TO APPEAR IN APJ LETTERS
Preprint typeset using LaTeX style emulateapj v. 05/04/06

CHAMPLANE DISCOVERY OF CANDIDATE SYMBIOTIC BINARIES IN BAADE'S AND STANEK'S WINDOWS

M. VAN DEN BERG[1], J. GRINDLAY[1], S. LAYCOCK[1], J. HONG[1], P. ZHAO[1], X. KOENIG[1], E. M. SCHLEGEL[2], H. COHN[3], P. LUGGER[3], R. M. RICH[4], A. K. DUPREE[1], G. H. SMITH[5], J. STRADER[5]

To appear in ApJ Letters

ABSTRACT

We have searched the *OGLE-II* archive for candidate counterparts of X-ray sources detected in two low-extinction windows included in our Galactic bulge *Chandra/HST* survey. We find that a significant number—i.e. in excess of the expected level of random associations—can be matched with probable M-giants. Their X-ray properties can be understood if these sources are symbiotic binaries where the X-rays are typically, either directly or indirectly, the result of a white dwarf accreting from the wind of a cool giant. Optical and near-infrared properties of selected sources are consistent with a symbiotic nature, although none of the spectra collected for 8 out of 13 candidate counterparts show the high-ionization nebular emission lines observed for many symbiotics. The hard X-ray emission for several sources (power-law photon indices $-1.5 \lesssim \Gamma \lesssim 1.5$) suggests our sample includes systems similar to the symbiotics recently detected with *INTEGRAL* and *Swift*.

Subject headings: X-rays: binaries — X-rays: stars — binaries: symbiotic — Galaxy: bulge — stars: late-type

1. INTRODUCTION

The main goal of the *Chandra* Multiwavelength Plane Survey (*ChaMPlane*[6]) is to identify and study the populations of low-luminosity ($L_X \lesssim 10^{33}$ erg s^{-1}) accretion-powered binaries in the Galaxy (Grindlay et al. 2005). *ChaMPlane* includes a deep survey of the Galactic bulge consisting of (near-)simultaneous *Chandra* and *Hubble Space Telescope* (*HST*) pointings of three low-extinction regions. With minimal obscuration by dust, for the bulge, and positions progressively closer to the Galactic Center (GC), these "windows" are chosen to trace the X-ray point-source population towards the GC. The bulge population of interacting binaries is also of interest for comparison with those in globular clusters, where stellar encounters have enhanced the numbers of close binaries, and with X-ray populations in other galaxies. Here we report initial results of observations of Baade's Window (*BW*, (l,b)=(1.°06,–3.°83)) and Stanek's Window (*SW*, (l,b)=(0.°25,–2.°15); Stanek 1998) where we have found a significant number of sources with candidate M-giant counterparts. In § 2 we describe the optical identification, and X-ray and optical/near-infrared spectra. As X-ray emission from single M-giants is rarely detected (Hünsch et al. 1998), we have investigated whether these sources could be symbiotic binaries in which a cool giant typically transfers mass to a white dwarf via a wind (§ 3). More results, including analysis of our "Limiting Window" at (l,b)=(0.°10,–1.°43) will be presented in future papers.

2. DATA AND ANALYSIS

2.1. *Chandra Data*

We obtained *Chandra*/ACIS-I observations of *BW* (obsid 3780; 98 ks) and *SW* on 2003 July 9 and 2004 February 14/15, respectively. The *SW* observation was split in two exposures of 80 ks (obsid 4547) and 19 ks (obsid 5303), with a gap of 1.^{h}2, to keep the same roll angle; these were stacked for the remainder of the analysis. The *ChaMPlane* X-ray data reduction pipeline (Hong et al. 2005) was used to create source lists from images in the 0.3–8 keV band and 95% confidence radii on positions $r_{95\%}$. A total of 365 (*BW*) and 389 (*SW*) ACIS-I sources were detected. Other pipeline products include net source counts between 0.5–8 keV, and energy quantiles E_x corresponding to the energies below which x% of the counts are detected.

2.2. *Optical Identification with OGLE-II Sources*

We searched the Optical Gravitational Lensing Experiment II (*OGLE-II*) star catalog (Udalski et al. 2002, U02 hereafter) for counterparts. Due to the high probability for spurious matches, we used only variable stars (Wozniak et al. 2002) to measure the *Chandra* boresight correction ($\sim 3\times10^5$ stars in the ACIS-I areas, versus $\sim 1\times10^3$ (*BW*) and $\sim 4\times10^3$ (*SW*) variables). As the U02 and Wozniak et al. catalogs are not cross-linked, we first identified the variables in U02 using match criteria based on difference in position (<2 pixels or $\sim$0.″82[7]) and I magnitude. We used the boresight method described in Zhao et al. (2005) adopting a 1 σ error on optical positions σ_o = 0.″2 (U02). The resulting *Chandra–OGLE II* offsets ($\Delta\alpha$, $\Delta\delta$) are (+0.″05(4),–0.″05(5)) and (+0.″22(3),–0.″40(3)), based on 26 and 49 matches in *BW* and *SW*, respectively. The light curves suggest many of these are interacting binaries for which we indeed expect enhanced X-rays. After correcting for boresight, we searched for counterparts in 2 σ radii, with σ the quadratic sum of σ_o, $r_{95\%}$ (normalized to 1σ) and the boresight error. To reduce spurious matches we only consider ACIS-I sources with $r_{95\%} \leq 3''$, yielding 351 and 384 *BW* and *SW* sources, for which 547 and 684 matches are found for 289 and 313 sources[8], respectively. Given several initial identifications with M-giants, bulge giants were selected to be at least as red (V–$I \geq 1.66$ for solar metallicity; Houdashelt et al. 2000) and at least as bright ($I \leq 13.4$ from 10 Gyr, Z = 0.019 isochrones by Girardi (2006)) as M0 III giants at the GC

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; maureen@head.cfa.harvard.edu
[2] Univ. of Texas, Dep. of Physics and Astronomy, San Antonio, TX 78249
[3] Indiana Univ., Dep. of Astronomy, Bloomington, IN 47405
[4] UCLA, Dep. of Physics and Astronomy, Los Angeles CA, 90095-1547
[5] Univ. of California Observatories/Lick Observatory, Dep. of Astronomy and Astrophysics, Santa Cruz, CA 95064
[6] http://hea-www.harvard.edu/ChaMPlane

[7] The catalogs are based on different photometry methods (direct versus difference imaging); therefore, stars included in both catalogs need not necessarily be listed with identical coordinates.
[8] including 33 and 73 stars without V–I color information

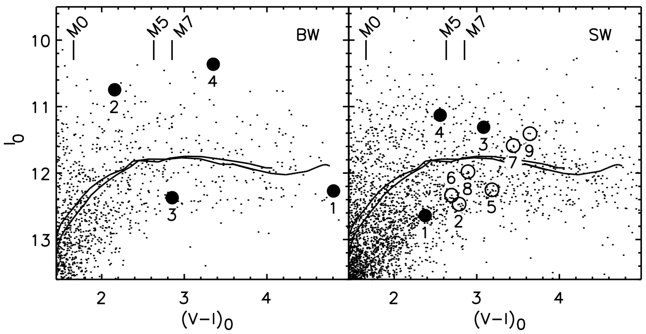

FIG. 1.— Color-magnitude diagrams for *BW* and *SW* (U02), corrected for the typical ($E(V–I)$, A_I)≈(0.84,0.81) in *BW* and (1.32,1.27) in *SW*. Matches from Table 1 are labeled; an open symbol indicates there are multiple U02-stars in the 2 σ match circle. The curves are the first and asymptotic giant branches of a Z=0.019, 10-Gyr isochrone (Girardi 2006) at 8 kpc; the spread of stars around the isochrone can be due to distance or non-solar compositions. Expected colors for M-giants are marked (Houdashelt et al. 2000).

(8 kpc). The maps by Sumi (2004)—based on photometry of bulge clump giants—were used to correct for reddening and extinction[9]. Four (*BW*) and 9 (*SW*) candidate counterparts satisfy the criteria (Table 1, Fig. 1). Repeating the matching for randomly offset X-ray positions (α and δ varied with 4.″5 increments on a 49×51 grid) shows that in *BW* the average number of M-giant counterparts found by chance $<N_g>$, is 1.3±1.1, and that $N_g \geq 4$ with 4.4% probability; in *SW* $<N_g>$=3.3±1.8, and $N_g \geq 9$ with 0.64% probability. Star counts by Zheng et al. (2001) predict $\lesssim$0.4 M-dwarfs in the ACIS-I area that can contaminate our sample.

The inner 6′×6′ of *BW* and *SW* were observed with the Advanced Camera for Surveys on *HST*. Optical identification using these data is the topic of future papers. We note that for the sources in Table 1 in the *HST* pointings (BW1 and 2) we find that all additional objects in the 2 σ match circles have colors consistent with them being late-type main-sequence stars at $\gtrsim$ 3 kpc, which would not normally be luminous enough for detection ($L_X \lesssim 10^{30}$ ergs s^{-1}, Schmitt & Liefke 2004) in our *Chandra* data.

2.3. *X-ray Spectral Properties*

Since most of the selected sources have only 10–30 counts, we use quantile analysis (Hong et al. 2004) to derive spectral information. Their median energies E_{50} are relatively high with all *BW* and 5 *SW* sources having $E_{50} \geq 2.5$ keV. Of all the detected sources in *BW* and *SW*, only 14% (*BW*) and 20% (*SW*) have $E_{50} \geq 2.5$ keV. Spectra for about half of the sources can be described with a bremsstrahlung model ($kT \gtrsim 1.5$ keV; Fig. 2a). The remaining sources are too hard; power-law models constrain their photon indices to $-1.5 \lesssim \Gamma \lesssim 1.5$ (Fig. 2b). Adding a broad 6.4 keV emission line brings these points even closer to the grid and increases Γ (Fig. 2c); this suggest the presence of a fluorescent Fe K line to avoid the unphysical $\Gamma \lesssim 0$ in the hardest sources. The column density n_H is consistent with the optically-derived value for bulge stars in *BW* and *SW*. An exception is SW3 for which the inferred n_H exceeds the field value by a factor of ∼15, suggesting the source is intrinsically absorbed. Table 1 summarizes quantile results for power-law models. Only for SW3, for which Γ is not well-constrained, is a bremsstrahlung model used to estimate n_H and kT.

For the two sources with ≥100 counts, source spectra were

[9] For foreground stars this is incorrect as $E(V–I)$ and A_I are overestimated. Foreground M-giants with $I \lesssim$11–12 would however be saturated in U02.

TABLE 1
PROPERTIES OF CANDIDATE M-GIANT COUNTERPARTS

ID	Counts	Γ[a]/ kT	n_H^a	logL_X[a] (8 kpc)	SpT[b] M...	*OGLE-II* ID[c]
BW1	10(5)	0.7	2.3	31.3(2)	3[b]	45/113191/1472
BW2	15(5)	0.7	2.6	31.5(2)	...	01/640074
BW3	12(5)	-1.2	2.2	31.7(2)	4–5[b]	45/256236/1224
BW4	30(7)	0.0	2.7	32.2(1)	...[b]	45/244411
SW1	521(26)	1.9	4.3	33.04(2)	...	39/126098
SW2	30(8)	2.6	4.5	31.8(1)	...	04/684358/4865
SW3	54(9)	1.5[a]	60[a]	32.88(7)	5–6	04/293339/4625
SW4	19(6)	1.1	3.8	31.6(1)	3	04/293323/4310
SW5	16(8)	1.5	4.1	31.5(2)	...	04/065565/3277
SW6	18(9)	1.2	4.2	31.6(2)	4–5	04/065539/3113
SW7	124(13)	0.6	4.1	32.48(4)	3–5	04/266999/2810
SW8	10(6)	1.0	4.1	31.3(3)	4–6	04/648022/2915
SW9	23(10)	1.0	4.5	31.8(2)	4–6	04/051718/2234

[a]X-ray properties refer to the 0.5–8 keV band. Power-law photon index Γ as derived from quantile power-law grids by fixing n_H (given in units of 10^{21} cm^{-2}) to the corresponding optically derived A_V for bulge stars (Sumi 2004) except for SW3 for which n_H and kT are derived from a thermal-bremsstrahlung grid (*see text*). For kT=1 keV thermal bremsstrahlung, 10^{-4} ct s^{-1} correspond to an unabsorbed flux of 1.36×10^{-15} (*BW*; n_H=2.5×10^{21} cm^{-2}) and 1.69×10^{-15} ergs cm^{-2} s^{-1} (*SW*; n_H=4.2×10^{21} cm^{-2}). To compute L_X (erg s^{-1}) a distance of 8 kpc is assumed.
[b]SpT=spectral type. Blanco et al. (1984) classify BW1 (their star 86) as M9, BW4 (star 93) as M6; Blanco (1986) give M5 for BW3 (star 83). A nearby bright star contaminates our spectra of BW1.
[c]IDs given as [field number]/[U02 ID]/ [Wozniak et al. (2002) ID].

TABLE 2
RESULTS OF SPECTRAL FITS (1 σ ERRORS)

ID	n_H[a]	Γ	χ^2_ν/dof	n_H[a]	kT (keV)	χ^2_ν/dof
SW1	(4.3)	2.0±0.1	0.52/22	(4.3)	$3.4^{+0.9}_{-0.6}$	0.60/22
	$2.6^{+0.7}_{-0.6}$	1.7±0.1	0.51/21	$2.2^{+0.7}_{-0.6}$	$6.0^{+6.4}_{-1.8}$	0.52/21
SW7	(4.1)	$0.44^{+0.68}_{-0.73}$	0.014/4	(4.1)	<335	0.27/4
	$8.4^{+12}_{-6.2}$	$0.72^{+0.72}_{-0.77}$	0.012/3	$17^{+13}_{-6.7}$	<159	0.05/3

[a]in units of 10^{21} cm^{-2}; values in parentheses are fixed in the fit

grouped to have $\geq$ 20 counts bin^{-1} and were corrected for background. We used *Sherpa* to fit power-law and thermal-bremsstrahlung models, and account for absorption by neutral hydrogen. Fixing n_H to the appropriate values from Sumi (2004) gave acceptable results for both sources, in agreement with quantile analysis; fitting for n_H does not yield significant improvements (Table 2).

2.4. *Optical and near-Infrared Spectra*

Optical spectra were obtained with the FLWO-1.5m FAST spectrograph in 2004 May and June (BW3; SW3, 4, 6, 7, 9), and the CTIO-4m Hydra multi-object spectrograph (BW1, 3; SW3, 6, 8, 9) in 2004 June and 2005 June. FAST spectra cover 3800–7500Å with 3Å resolution while Hydra spectra cover 4000–6800Å with 4.9Å resolution. Stars were classified using templates in Silva & Cornell (1992) and TiO-band strengths (Kenyon & Fernandez-Castro 1987), see Table 1. Hα, and Hα and Hβ are in emission in SW7 and 9, respectively, but no strong high-ionization emission lines (often present in spectra of symbiotics, see § 3) are observed. No variability is seen for stars observed in multiple runs.

Near-infrared spectra of the He I 1.083 μ line were obtained for BW3 and SW7 on 2005 May 19 using Keck-II/NIRSPEC in high-resolution cross-dispersed echelle mode. Each observation consisted of a single AB nod pair of exposures with 900 s integrations at both slit positions. Strong P-Cygni profiles are seen, indicative of wind velocities of 230 (BW3)

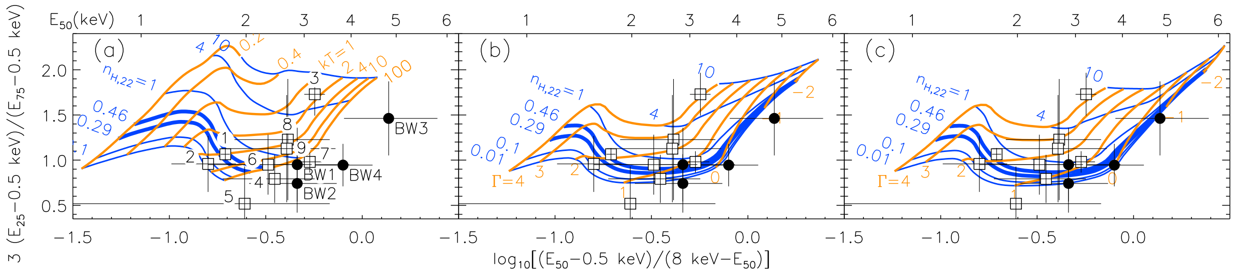

FIG. 2.— Quantile color-color diagrams for absorbed (*a*) thermal-bremsstrahlung models, (*b*) power-law models and (*c*) power-law models plus a 6.4 keV gaussian emission line (1 keV equivalent width), showing the sources in Table 1 as circles (*BW*) and squares (*SW*). Grey/orange and black/blue lines indicate a fixed kT (in keV) or Γ and $n_{H,22} \equiv n_H/10^{22}\,\mathrm{cm}^{-2}$, respectively. Spectral properties of a source can be derived from its position in the grid; for example, following a grey/orange line in (*a*) from lower left to upper right traces a source of given kT absorbed by an increasingly larger n_H. Thick lines indicate the average n_H for bulge stars in *BW* and *SW*. The top axis shows the median energy E_{50}. *See electronic edition for color figure.*

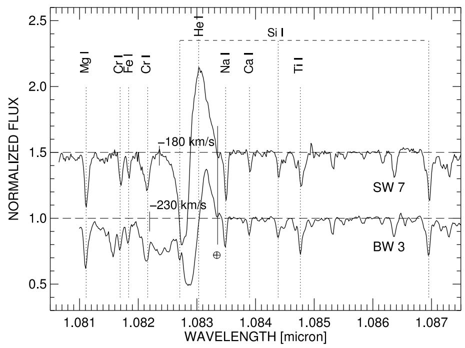

FIG. 3.— NIRSPEC spectra of BW3 and SW7 with identified features.

and 180 km s^{-1} (SW7; Fig. 3). Similar profiles in ultraviolet lines are found in symbiotic star systems, for example AG Dra (Young et al. 2005). Single M-giants do not show He I 1.083 μ with the emission strength and absorption as in BW3 and SW7 (Lambert 1987).

3. DISCUSSION AND CONCLUSIONS

We explore possible explanations for the X-ray emission from these giants. Single M-giants are rarely detected in X-rays but Hünsch et al. (2004) point out a few candidates that are matched securely to X-ray sources ($L_{0.5\text{–}8\mathrm{keV}} = (0.1\text{–}1.1)\times 10^{31}$ erg s^{-1} for a 10^7 K coronal plasma, but L is $\sim$15 times larger for a $\Gamma = 0$ power law, for $n_H = 0$ cm^{-2}). Their X-rays are yet unexplained, but the absence of optical emission lines is used to argue against a symbiotic nature. In RS CVn binaries, activity of a (sub)giant is increased by tidal coupling of the stellar rotation to the orbit, but no RS CVns with M-giants are known. Tidal forces in a detached binary wide enough to fit an M-giant are too weak to spin up a main-sequence companion. Moreover, neither single stars nor active binaries are in general as hard as some of our sources.

Of the $\sim$200 symbiotic binaries currently known, $\sim$80% contain an M3–6 red giant (Mürset & Schmid 1999). Mass transfer occurs mostly via a wind as opposed to Roche-lobe overflow. Mürset et al. (1997) show in a ROSAT study that symbiotics are typically soft; nuclear burning on the white dwarf produces very soft emission ($\lesssim$ 0.4 keV), while somewhat harder X-rays are associated with hot ($kT \approx 1$ keV) shocked gas in the colliding winds of the giant and hot star. Note that our sample contains many hard sources ($\gtrsim$ 50%, §2.3) that may be similar to the hardest sources in Mürset et al. Emission above a few keV is so far poorly studied for symbiotics; possible explanations include accretion (CH Cyg; Ezuka et al. 1998) or shocked gas (Z And; Sokoloski et al. 2006). Recently, symbiotics have been detected also in very hard X-rays by *INTEGRAL* and *Swift* (e.g. RT Cru, Tueller et al. 2005). X-ray luminosities of symbiotics range from 10^{29} to 10^{34} erg s^{-1}, up to $\sim 10^{37}$ erg s^{-1} for the neutron-star accretor GX 1+4.

We estimate the upper limit on the temperature of the shock-heated gas in the colliding-wind model by requiring that the thermal energy per gas particle does not exceed the kinetic energy. A wind velocity $v_w = 230$ km s^{-1} gives $kT \lesssim 0.2$ keV, lower than implied for any of our sources by quantile analysis. Thus, if the He I 1.083 μ lines in BW3 and SW7 (two of the hardest sources) trace the conditions in the shocked winds, this model is an unlikely explanation. To reach $kT \approx 1.5$ keV as in SW3, requires $v_w \approx 660$ km s^{-1}. A mass-loss rate $\dot{M} = 10^{-7}\ M_\odot$ yr^{-1} gives a total kinetic luminosity $1/2\,\dot{M}v_w^2 \approx 2.7\times 10^{34}$ erg s^{-1}, sufficient to power $L_{0.5\text{–}8\mathrm{keV}} = 7.6\times(d/8\mathrm{kpc})^2\times 10^{32}$ erg s^{-1} for SW3. Looking for such fast outflows would be one test whether shocked winds are indeed a plausible explanation for our soft sources.

To check whether accretion is a viable source of X-rays, we use Eq. 3 from Livio & Warner (1984) for the total accretion luminosity L_{acc}. We choose masses for the giant and white dwarf of 1 and 0.6 $M_\odot$, a white-dwarf radius of 10^9 cm, $\dot{M} = 10^{-7}\ M_\odot$ yr^{-1}, and $v_w = 230$ km s^{-1}; the orbital speed of the white dwarf is assumed to be large compared to the local sound speed. The range of known orbital periods P_b for symbiotics (200–5700 d) implies $6\times 10^{34} \gtrsim L_{acc} \gtrsim 7\times 10^{33}$ erg s^{-1}, scaling linearly with $\dot{M}$. Thus it is likely that accretion onto a white dwarf can power the X-rays: $L_{0.5\text{–}8\mathrm{keV}} = (2.0\text{–}110)\times(d/8\,\mathrm{kpc})^2\ 10^{31}$ erg s^{-1} (Table 1). Accretion onto a neutron star is less probable: for a 1.4 $M_\odot$, $R = 15$ km companion, $L_{acc} \gtrsim 10^{35}$ erg s^{-1} for the assumed $\dot{M}$.

Assuming we observe the white dwarf through the giant's wind, we estimate n_H for the simplified case of a circular orbit and a spherically symmetric neutral-hydrogen wind of constant velocity: $n_H \approx \dot{M}/(16 m_H v_w a)\ (\cos^2 i + \sin^2\phi \sin^2 i)^{-1/2}$, with a the semi-major axis, i the orbital inclination, and ϕ the orbital phase. For the parameters and range in P_b as above, $9\times 10^{19} \lesssim n_H \lesssim 2\times 10^{21}$ cm^{-2} for $i = 60°$, below or similar to the Galactic n_H for *BW* and *SW*. Seaquist & Taylor (1990) have found a mass-loss rate $\dot{M} \approx 10^{-8}\text{–}10^{-6}\ M_\odot$ yr^{-1} for red-giant symbiotics which allows for an enhanced n_H, but values as high as for SW3 also require a larger i. Quantile analysis suggests 6.4 keV Fe K emission in our hardest sources, which may be another manifestation of the giant's cool wind via interaction with hard X-rays; Fe K lines are observed in e.g. CH Cyg (Ezuka et al. 1998) and RT Cru (J. Sokoloski 2006, private communication).

How do other properties of our sources compare to those of M-giants and symbiotics? Variability and mass loss, both associated with stellar pulsations, are typical properties of single late M-giants. Glass & Schultheis (2002) found that many M5 and all M6 and later giants in Baade's Window are variables. Of the 10 matches included in Wozniak et al. (2002), the matches to BW1, SW7, 9, and possibly SW3, 4, 5 and 8 show semi-regular variability as commonly observed in late M-giants (amplitudes $\lesssim 2.5$ mag, time scales 20–200 d). Glass & Schultheis (2002) note that BW3 however shows more regular variability. The period they find in *MACHO* data (135.5d) is the same as what we find in *OGLE-II* data (135.2±1.5d). If this is due to ellipsoidal variations then $P_b \approx 270$ d. Variability of SW2, 6 and possibly 8 is irregular with $\Delta I \lesssim 0.1$ in 4 seasons. From mid-infrared photometry Alard et al. (2001) derive $\dot{M} \approx 4\times10^{-7}$ and 4×10^{-8} $M_\odot$ yr^{-1} for the matches to BW1 and 4, respectively. Outflow velocities for BW3 and SW7 are high for single red giants ($v_w \approx 10$–30 km s^{-1}) but a similar velocity has been derived from He I 1.083μ for GX 1+4 (Chakrabarty et al. 1998).

Optical spectra of our matches lack strong high-ionization nebular emission lines. The presence of such lines is one of the original defining properties of symbiotics. Examples of "weakly symbiotic" (i.e. without strong nebular emission) systems that are hard in X-rays are 4U 1700+24 and 4U 1954+319 (both suspected neutron-star systems that look like "normal" M-giants in the optical, Masetti et al. 2006) and the aforementioned *INTEGRAL* and *Swift* sources, for which Hα and Hβ are the strongest optical emission lines. If these are similar to our sources, the large fraction of such systems in our sample then suggests these properties are characteristic for a bulge sub-population and/or not identified previously due to sensitivity limits or limited astrometric precision. Further study of the *BW* and *SW* sources but also those of Hünsch et al. (2004) is therefore of interest for estimates of the total number of Galactic symbiotics and their progeny, which may include SNIa systems. The evolution of symbiotics depends on the orbital period. Long-period systems become wide double white dwarfs. For P_b = 270 d as for BW3, and 1 and 0.6 $M_\odot$ stars, the Roche-lobe radius is likely $\sim 94R_\odot$. In the models by Lejeune & Schaerer (2001), a $1M_\odot$ star reaches $R \approx 110R_\odot$ at the tip of the red-giant branch and expands even further as an asymptotic giant. If BW3 is a binary, it may start unstable mass transfer leaving a close double white dwarf, which could evolve to a SN Ia.

We use the results by Laycock et al. (2005) to constrain the number of symbiotics among the initial sample of 1453 still unclassified faint, hard X-ray sources in the $10' \times 10'$ region around the GC (Muno et al. 2003). For $A_{K,GC} \approx 3.4$ and $M_K \lesssim -4$, $K \lesssim 13.9$ for M-giants at the GC. Laycock et al. find that $\lesssim 7\%$ (90% confidence) of the 110 hard sources within $1'$ from the GC can have counterparts with $K \leq 14$, while this is true for $\leq 4\%$ of the 1343 hard sources at larger offsets. These likely include high-mass X-ray binaries with B0 V primaries but also symbiotics.

We thank J. Sokoloski for discussions and comments on the manuscript. This work is supported by Chandra grants GO3-4033A and AR6-7010X. We are grateful for the use of the Keck Observatory on Mauna Kea.

REFERENCES

Alard, C. et al. 2001, ApJ, 552, 289
Blanco, V. 1986, AJ, 91, 290
Blanco, V., McCarthy, M., & Blanco, B. 1984, AJ, 89, 636
Chakrabarty, D., van Kerkwijk, M. H., & Larkin, J. E. 1998, ApJ, 497, L39+
Ezuka, H., Ishida, M., & Makino, F. 1998, ApJ, 499, 388
Girardi, L. 2006, http://pleiadi.pd.astro.it
Glass, I. S., & Schultheis, M. 2002, MNRAS, 337, 519
Grindlay, J. et al. 2005, ApJ, 635, 920
Hong, J., Schlegel, E. M., & Grindlay, J. E. 2004, ApJ, 614, 508
Hong, J., van den Berg, M., Schlegel, E., Grindlay, J., Koenig, X., Laycock, S., & Zhao, P. 2005, ApJ, 635, 907
Houdashelt, M., Bell, R., Sweigart, A., & Wing, R. F. 2000, AJ, 119, 1424
Hünsch, M., Konstantinova-Antova, R., Schmitt, J., Schröder, K.-P., Kolev, D., de Medeiros, J.-R., Lèbre, A., & Udry, S. 2004, in IAU Symp., 223
Hünsch, M., Schmitt, J., Schröder, K.-P., & Zickgraf, F.-J. 1998, A&A, 330, 225
Kenyon, S. J., & Fernandez-Castro, T. 1987, AJ, 93, 938
Lambert, D. L. 1987, ApJS, 65, 255
Laycock, S., Grindlay, J., van den Berg, M., Zhao, P., Hong, J., Koenig, X., Schlegel, E., & Persson, S. E. 2005, ApJ, 634, L53
Lejeune, T., & Schaerer, D. 2001, A&A, 366, 538
Livio, M., & Warner, B. 1984, The Observatory, 104, 152
Masetti, N., Orlandini, M., Palazzi, E., Amati, L., & Frontera, F., A&A, in press (astro-ph/0603227)
Muno, M. P. et al. 2003, ApJ, 589, 225
Mürset, U., & Schmid, H. M. 1999, A&AS, 137, 473
Mürset, U., Wolff, B., & Jordan, S. 1997, A&A, 319, 201
Schmitt, J. H. M. M., & Liefke, C. 2004, A&A, 417, 651
Seaquist, E. R., & Taylor, A. R. 1990, ApJ, 349, 313
Silva, D. R., & Cornell, M. E. 1992, ApJS, 81, 865
Sokoloski, J. L. et al. 2006, ApJ, 636, 1002
Stanek, K. Z. 1998, astro-ph/9802307
Sumi, T. 2004, MNRAS, 349, 193
Tueller, J., Gehrels, N., Mushotzky, R., Markwardt, C., Kennea, J., Burrows, D., Mukai, K., & Sokoloski, J. 2005, The Astronomer's Telegram, 591, 1
Udalski, A. et al. 2002, Acta Astronomica, 52, 217 (U02)
Wozniak, P. R., Udalski, A., Szymanski, M., Kubiak, M., Pietrzynski, G., Soszynski, I., & Zebrun, K. 2002, Acta Astronomica, 52, 129
Young, P. R., Dupree, A. K., Espey, B. R., Kenyon, S. J., & Ake, T. B. 2005, ApJ, 618, 891
Zhao, P., Grindlay, J., Hong, J., Laycock, S., Koenig, X., Schlegel, E., & van den Berg, M. 2005, ApJS, 161, 429
Zheng, Z., Flynn, C., Gould, A., Bahcall, J. N., & Salim, S. 2001, ApJ, 555, 393